

## THE MODERNIZED

# metric system

**The International System of Units-SI** is a modernized version of the metric system established by international agreement. It provides a logical and interconnected framework for all measurements in science, industry, and commerce. Officially abbreviated SI, the system is built upon a foundation of seven base units, plus two supplementary units, which appear on this chart along with their definitions. All other SI units are derived from these units. Multiples and sub-multiples are expressed in a decimal system. Use of metric weights and measures was legalized in the United States in 1866, and since 1893 the yard and pound have been defined in terms of the meter and the kilogram. The base units for time, electric current, amount of substance, and luminous intensity are the same in both the customary and metric systems.

### COMMON CONVERSIONS

Accurate to Six Significant Figures

Symbol	When You Know	Multiply by	To Find	Symbol
in	inches	$\times 25.4$	millimeters	mm
ft	feet	$\times 0.3048$	meters	m
yd	yards	$\times 0.9144$	meters	m
mi	miles	$\times 1.609\ 34$	kilometers	km
yd <sup>2</sup>	square yards	$\times 0.836\ 127$	square meters	m <sup>2</sup>
	acres	$\times 0.404\ 686$	hectares	ha
yd <sup>3</sup>	cubic yards	$\times 0.764\ 555$	cubic meters	m <sup>3</sup>
qt	quarts (liq)	$\times 0.946\ 353$	liters	l
oz	ounces (avdp)	$\times 28.349\ 5$	grams	g
lb	pounds (avdp)	$\times 0.453\ 592$	kilograms	kg
$^{\circ}\text{F}$	Fahrenheit temperature	$\times 5/9$ (after subtracting 32)	Celsius temperature	$^{\circ}\text{C}$
mm	millimeters	$\times 0.039\ 370\ 1$	inches	in
m	meters	$\times 3.280\ 84$	feet	ft
m	meters	$\times 1.093\ 61$	yards	yd
km	kilometers	$\times 0.621\ 371$	miles	mi
m <sup>2</sup>	square meters	$\times 1.195\ 99$	square yards	yd <sup>2</sup>
ha	hectares	$\times 2.471\ 05$	acres	ac
m <sup>3</sup>	cubic meters	$\times 1.307\ 95$	cubic yards	yd <sup>3</sup>
l	liters	$\times 1.056\ 69$	quarts (liq)	qt
g	grams	$\times 0.035\ 274\ 0$	ounces (avdp)	oz
kg	kilograms	$\times 2.204\ 62$	pounds (avdp)	lb
$^{\circ}\text{C}$	Celsius temperature	$\times 9/5$ (then add 32)	Fahrenheit temperature	$^{\circ}\text{F}$

### MULTIPLES AND PREFIXES

These Prefixes May Be Applied To All SI Units

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 000 = $10^{15}$	tera (tér'a)	T
1 000 000 000 000 = $10^{12}$	giga (jí'gá)	G
1 000 000 000 = $10^9$	mega (meg'a)	M
1 000 = $10^3$	kilo (kíl'ó)	k
100 = $10^2$	hecto (hék'tó)	h
10 = $10^1$	deka (dék'a)	da
Base Unit = $10^0$		
0.1 = $10^{-1}$	deci (des'i)	d
0.01 = $10^{-2}$	centi (sén'ti)	c
0.001 = $10^{-3}$	milli (míl'i)	m
0.000 001 = $10^{-6}$	micro (mík'rō)	μ
0.000 000 001 = $10^{-9}$	nano (nān'ō)	n
0.000 000 000 001 = $10^{-12}$	pico (pí'kō)	p
0.000 000 000 000 001 = $10^{-15}$	femto (fém'tō)	f
0.000 000 000 000 000 001 = $10^{-18}$	atto (át'tō)	a

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 REFERENCES  
 NBS Special Publication 330, 1972 Edition, International System of Units (SI), available by purchase from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402, order as C13.10-330/2; 30 cents a copy.  
 ASTM Metric Practice Guide E880-72, available by purchase from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103, \$1.50 a copy, minimum order \$3.00.  
 Rules for the Use of Units of the International System of Units, order as ISO Recommendation R1000; \$1.25 a copy, from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

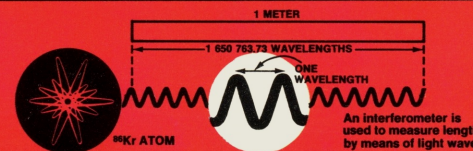
<sup>a</sup>exact  
<sup>b</sup>for example, 1 in. = 25.4 mm, so 3 inches would be (3 in.) (25.4 mm/in.) = 76.2 mm  
<sup>c</sup>hectare is a common name for 10 000 square meters  
<sup>d</sup>liter is a common name for fluid volume of 0.001 cubic meter  
 Note: Most symbols are written with lower case letters; exceptions are units named after persons for which the symbols are capitalized. Periods are not used with any symbols.

U.S. DEPARTMENT OF COMMERCE  
 NATIONAL BUREAU OF STANDARDS



## meter-m LENGTH

The meter (common international spelling, metre) is defined as 1 650 763.73 wavelengths in vacuum of the orange-red line of the spectrum of krypton-86.



The SI unit of area is the **square meter** (m<sup>2</sup>).

The SI unit of volume is the **cubic meter** (m<sup>3</sup>). The liter (0.001 cubic meter), although not an SI unit, is commonly used to measure fluid volume.

## kilogram-kg MASS

The standard for the unit of mass, the kilogram, is a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures at Paris. A duplicate in the custody of the National Bureau of Standards serves as the mass standard for the United States. This is the only base unit still defined by an artifact.



The SI unit of force is the **newton** (N). One newton is the force which, when applied to a 1 kilogram mass, will give the kilogram mass an acceleration of 1 (meter per second) per second.  
 $1\text{ N} = 1\text{ kgm/s}^2$



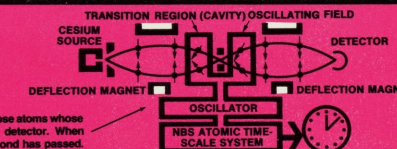
The SI unit for pressure is the **pascal** (Pa).  
 $1\text{ Pa} = 1\text{ N/m}^2$

The SI unit for work and energy of any kind is the **joule** (J).  
 $1\text{ J} = 1\text{ N}\cdot\text{m}$

The SI unit for power of any kind is the **watt** (W).  
 $1\text{ W} = 1\text{ J/s}$

## second-s TIME

The second is defined as the duration of 9 192 631 770 cycles of the radiation associated with a specified transition of the cesium-133 atom. It is realized by tuning an oscillator to the resonance frequency of cesium-133 atoms as they pass through a system of magnets and a resonant cavity into a detector.



Schematic diagram of an atomic beam spectrometer or "clock." Only those atoms whose magnetic moments are "flipped" in the transition region reach the detector. When 9 192 631 770 oscillations have occurred, the clock indicates one second has passed.

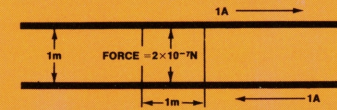
The number of periods or cycles per second is called frequency. The SI unit for frequency is the **hertz** (Hz). One hertz equals one cycle per second.

The SI unit for speed is the **meter per second** (m/s).

The SI unit for acceleration is the **(meter per second) per second** (m/s<sup>2</sup>).

## ampere-A ELECTRIC CURRENT

The ampere is defined as that current which, if maintained in each of two long parallel wires separated by one meter in free space, would produce a force between the two wires (due to their magnetic fields) of  $2 \times 10^{-7}$  newton for each meter of length.

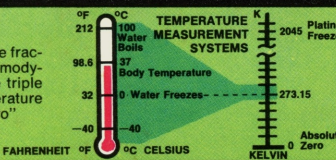


The SI unit of voltage is the **volt** (V).  
 $1\text{ V} = 1\text{ W/A}$

The SI unit of electric resistance is the **ohm** (Ω).  
 $1\ \Omega = 1\text{ V/A}$

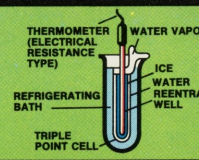
## kelvin-K TEMPERATURE

The kelvin is defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. The temperature 0 K is called "absolute zero".



On the commonly used Celsius temperature scale, water freezes at about 0 °C and boils at about 100 °C. The °C is defined as an interval of 1 K, and the Celsius temperature 0 °C is defined as 273.15 K.

The Fahrenheit degree is an interval of  $5/9^{\circ}\text{C}$  or  $5/9\text{ K}$ . The Fahrenheit scale uses 32 °F as a temperature corresponding to 0 °C.



The standard temperature at the triple point of water is provided by a special cell, an evacuated glass cylinder containing pure water. When the cell is cooled until a mantle of ice forms around the reentrant well, the temperature at the interface of solid, liquid, and vapor is 273.16 K. Thermometers to be calibrated are placed in the reentrant well.

## mole-mol AMOUNT OF SUBSTANCE

The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12.

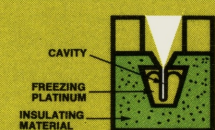


When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

The SI unit of concentration (of amount of substance) is the **mole per cubic meter** (mol/m<sup>3</sup>).

## candela-cd LUMINOUS INTENSITY

The candela is defined as the luminous intensity of 1/600 000 of a square meter of a blackbody at the temperature of freezing platinum (2045 K).



The SI unit of light flux is the **lumen** (lm). A source having an intensity of 1 candela in all directions radiates a light flux of 4 π lumens.



A 100-watt light bulb emits about 1700 lumens

## TWO SUPPLEMENTARY UNITS

## radian-rad PLANE ANGLE

The radian is the plane angle with its vertex at the center of a circle that is subtended by an arc equal in length to the radius.



## steradian-sr SOLID ANGLE

The steradian is the solid angle with its vertex at the center of a sphere that is subtended by an area of the spherical surface equal to that of a square with sides equal in length to the radius.

